STANDARDS DEVELOPMENT BRANCH OMOE

CONTROL OF FIRES AND EXPLOSIONS AT THE EXPERIMENTAL PLANT FOR RESOURCE RECOVERY

NOVEMBER 1980

TD
794.5
.A35
C66
1980

Ministry
of the
Environment

Ontario

The Honourable
Harry C. Parrott, D.D.S.,
Minister

Graham W. S. Scott, Q.C.,
Deputy Minister

Copyright Provisions and Restrictions on Copying:

This Ontario Ministry of the Environment work is protected by Crown copyright (unless otherwise indicated), which is held by the Queen's Printer for Ontario. It may be reproduced for non-commercial purposes if credit is given and Crown copyright is acknowledged.

It may not be reproduced, in all or in part, part, for any commercial purpose except under a licence from the Queen's Printer for Ontario.

For information on reproducing Government of Ontario works, please contact Service Ontario Publications at copyright@ontario.ca

CONTROL OF
FIRES AND EXPLOSIONS
AT THE
EXPERIMENTAL PLANT FOR RESOURCE RECOVERY

N.R. Ahlberg, P.Eng.

and

B.I. Boyko, P.Eng.

Ontario Ministry of the Environment
Waste Management Branch

NOVEMBER 1980

TD
794.5
.A35
C66
1980

TABLE OF CONTENTS

SUMMARY 1

INTRODUCTION 2

DESCRIPTION OF FACILITIES 3

BACKGROUND. 3

ORIGINAL LOSS CONTROL MEASURES 5

THE FIRE PROBLEM 8
- Fire Areas 8
- Fire Incidents 9
- Fire Fighting Considerations. 11
- Fire Loss Control System Modifications 14

THE EXPLOSION PROBLEM 16
- December 4, 1978 16
- December 21, 1978. 17
- March 29, 1979 19
- April 19, 1979 19
- December 6, 1979 21
- April 29, 1980 23
- May 15, 1980 23
- Common Aspects 25

LOSS CONTROL MEASURES 26
- Investigations 26
- Plant Modifications 34
- Performance of Loss Control Measures 38

CONCLUSIONS. 39

RECOMMENDATIONS. 40

REFERENCES 41

LIST OF FIGURES

Page

Figure 1 Experimental Plant For Resource Recovery 4

Figure 2 Primary Shredder - Air Separator Original Fire Protection System 7

Figure 3 Explosion Damage December 21, 1978 18

Figure 4 Explosion Damage March 29, 1979 20

Figure 5 Explosion Damage April 19, 1979. 22

Figure 6 Explosion Damage December 6, 1979 24

Figure 7 Hydrocarbon Concentration in Shredder Feed Area - Commercial Waste 29

Figure 8 Hydrocarbon Concentration in Shredder Feed Area - Residential Waste 30

Figure 9 Histogram of Hydrocarbon Peaks - Commercial Waste 31

Figure 10 Histogram of Hydrocarbon Peaks - Residential Waste 32

Figure 11 Primary Shredder Venting (Plan) 35

Figure 12 Primary Shredder Venting (Sections) 36

LIST OF TABLES

Page

TABLE 1 Location of Fires 10

TABLE 2 Downtime from Fires 12

SUMMARY

The Experimental Plant for Resource Recovery has experienced four major explosions and over seventy fires in the first two and one half years of operation, primarily in the shredding area of the solid waste processing facilities. This report reviews the effectiveness of various loss control measures based on this operating experience. The original plant features, details of fire and explosion incidents, loss control system modifications, and the results of studies both on hydrocarbon and dust explosion hazards and on explosion protection systems are presented and discussed.

Modifications to the original fire protection system included the addition of a manually activated water deluge in the shredder feed and discharge areas, carbon dioxide extinquishing systems for the pneumatic conveying systems, sprinkler protection for the fibre storage bins, and modification of sprinkler systems to overcome cold weather problems. The modifications and additions to the sprinkler system were primarily to protect general plant areas likely to experience fires after normal operating hours; the relatively slow response of sprinklers is suited to this application and have been instrumental in containing several fires on the receiving floor. The water deluge and carbon dioxide systems were to provide rapid response to a processing situation. The carbon dioxide system has not yet been involved in actual fire incidents. The water deluge system has been used repeatedly in fires and is a major factor in minimizing damage in the Experimental Plant; another significant factor is the rapid response of properly trained staff. The current fire protection systems have proven adequate to protect the plant facilities.

The major loss control modification resulting from explosions has been the installation of vents on the primary shredder. Their value has already been realized in minimizing damage in explosions following their installation. More stringent waste inspection prior to shredding has failed to completely eliminate explosion incidents, as expected, but continued inspection may reduce the frequency or severity of further incidents. Explosions remain an inevitable possibility in the processing of solid waste; however, their effects can be minimized by attention to loss control measures both in design and operation of shredding facilities.

INTRODUCTION

The Ontario Ministry of the Environment's \$15.0 million Experimental Plant for Resource Recovery (ERRP), a production size research and development facility, commenced resource recovery operations in April, 1978. The principal objectives of the ERRP are to provide information on the technology and economics of resource recovery and to provide a regular supply of recovered resources for product utilization and market development.

The plant features facilities both to transfer waste, as received, and to process and recover materials and energy from waste. Facilities design and construction management were carried out by Kilborn Ltd. for the Ministry of the Environment. Plant operation and direct management is the responsibility of Browning-Ferris Industries of Toronto Ltd. under terms of a five-year operating contract awarded by the Ministry.

The Ministry of the Environment, Waste Management Branch, is responsible for the overall facility management, including in-plant data collection, sampling and analyses, R & D, performance assessment, and product marketing and market development.

After processing approximately 42,000 tonnes of refuse, the resource recovery facility has experienced 4 major explosions, 3 minor explosions, and 66 fires. A possible contributor to this high frequency of incidents is the fact that the ERRP processes approximately 70 to 80 percent commercial and industrial waste.

In keeping with the technology transfer objective, this report reviews the fire and explosion incidents encountered at the ERRP. General plant design is reviewed with emphasis on the original precautions and protection systems provided for fire and explosion loss control. Details of the fire and explosion incidents are also presented along with the results of hydrocarbon monitoring and dust analyses. A review is made of plant modifications and changes in operating procedures undertaken to reduce both the frequency of such incidents as well as the magnitude of plant losses inevitably incurred. The effectiveness of these loss control measures is discussed.

DESCRIPTION OF FACILITIES

The ERRP is located on a 7 hectare site in the Borough of North York, Metropolitan Toronto. Through an agreement with Metropolitan Toronto, general municipal solid waste, as collected from residential and commercial sources is directed to the plant. Hazardous materials, such as pathological or chemical wastes, and non-processable materials, such as demolition wastes, are not received.

The plant comprises the following components:

- scalehouse;
- receiving, transfer, and paper recovery building;
- shredding and air separation/classification buildings;
- commodity and energy recovery building; and
- composting building.

Figure 1 is a general view of the Experimental Plant for Resource Recovery.

All waste processing, except composting, is done on a dry, as received, basis. Equipment was designed for an average capacity of 36 tonnes/hour with a peak capacity of 54 tonnes/hour; the plant was also designed to receive an additional 550 tonnes daily, in a single shift, and transfer out this tonnage without processing in 57 m^3 compaction trailers for hauling to landfill sites. The direct transfer facilities not only provide an immediate service to the area, but also increase the overall versatility of the plant.

The research and development facilities of the ERRP are described in detail elsewhere (1).

Operation of the transfer station commenced in March, 1977, and the resource recovery facility was in complete operation in July 1978. Total tonnage transferred to the end of October 1980 was 442,000 tonnes; resource recovery process tonnage to the end of October 1980 was 42,000 tonnes.

BACKGROUND

The widespread occurrence of explosions associated with the shredding of municipal solid waste was probably first brought to the industry's attention by Zalosh (2).

RESOURCE RECOVERY
ONTARIO MINISTRY OF THE ENVIRONMENT

EXPERIMENTAL PLANT
FOR RESOURCE RECOVERY
NORTH YORK, ONTARIO

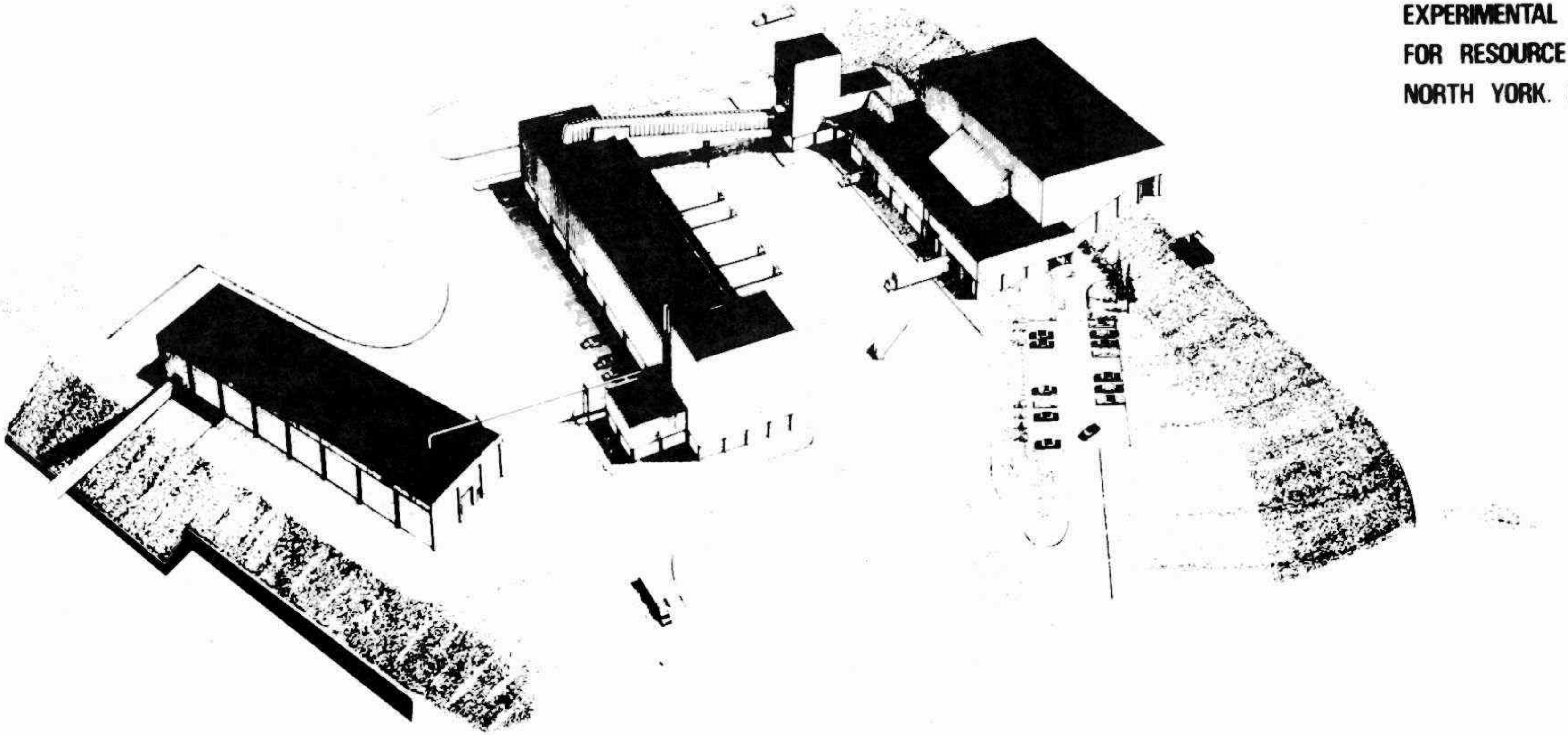

Figure 1 Experimental Plant For Resource Recovery

His report indicated that 76 percent of the shredding installations surveyed had experienced at least one explosion. It was also concluded that preventative measures such as manual or automatic inspections of shredder input could not be expected to eliminate explosions entirely. Instead, emphasis should be placed on damage control measures.

In response to this increasing concern over the explosion hazards of solid waste shredding, the ASTM Committee E-38 on Resource Recovery established an Explosion Protection task group within its sub-committee E-38.07 on Health and Safety. One of the major activities of this task force is the assembly of a list of recommended practices for the safe operation of refuse processing equipment.

The U.S. Environmental Protection Agency is currently funding a study of explosion venting which is being undertaken by the Factory Mutual Research Corporation.

Recognizing the need to protect staff and equipment at their waste handling facilities, the Municipality of Metropolitan Toronto has always had a list of materials prohibited at transfer stations. This list includes "flammable, explosive or other hazardous material, including paints and paint thinners" among the nine categories of prohibited materials; identical regulations are in force for waste receipts at the ERRP. Even though flammable and explosive materials are prohibited, numerous fire and explosion incidents have been experienced at the plant.

As expected, most of the incidents have occurred in the primary shredding area with a few instances of fires on the receiving floor and in the commodity recovery building. Since all waste processing except composting is done on a dry as received basis, there is considerable potential for a rapid spreading of fire either through the pneumatic conveying systems or along conveyor systems having a material burden.

ORIGINAL LOSS CONTROL MEASURES

Fire protection provided under the original plant design consisted of sprinkler protection in accordance with the local building code, sprinkler protection for the receiving floor, and a fire protection system for the primary shredder discharge and associated air separation/classification system.

Ionization detectors with remote plant alarms were also provided at the primary shredder feed hood, double piston baler feed hopper, and at the head pulley of the conveyor belt carrying the heavy stream for further processing.

Smoke detectors were also provided in the plant's electrical rooms. The electrical room smoke detectors and low water pressure and water flow indicators for the sprinkler systems are continuously monitored by a security service; the fire department is immediately notified upon an alarm indication. The on-site plant security service also provides for routine inspections during non-operational hours.

The basic elements of the fire protection system within the resource recovery processing line are shown in Figure 2. The operational sequence of events for this system is as follows:

1. Fire detected either through a heat sensor located in the primary shredder discharge conveyor or through the television monitoring system;
2. Fire protection sytem activated, resulting in:
3. Deluge system in the discharge vibrating conveyor turns on;
4. Clam gate in the air separator opens breaking pickup suction;
5. Gate in the pneumatic conveying line opens breaking conveying suction;
6. Diverter gate at the end of the heavies conveyor redirects all material outside commodity recovery building.

All of these actions take place simultaneously rather than sequentially. With all of the fires experienced in the primary shredder, the performance of this downstream fire loss control system has been excellent. However, the ionization detectors mentioned earlier, installed to serve as warning devices, have proved to be virtually useless, likely the result of excessive dust concentrations in the areas of application. Consequently, modifications were required to provide adequate fire protection in the area immediately upstream from the primary shredder.

Similarly, a number of precautions were taken at the time of plant design to provide explosion loss control measures in the area of the primary shredder. These measures included:

1. Isolation of the primary shredder from other processing buildings;
2. Providing explosion doors on the primary shredder;
3. Manual inspection of refuse prior to being processed;
4. Remote operation of the shredder;

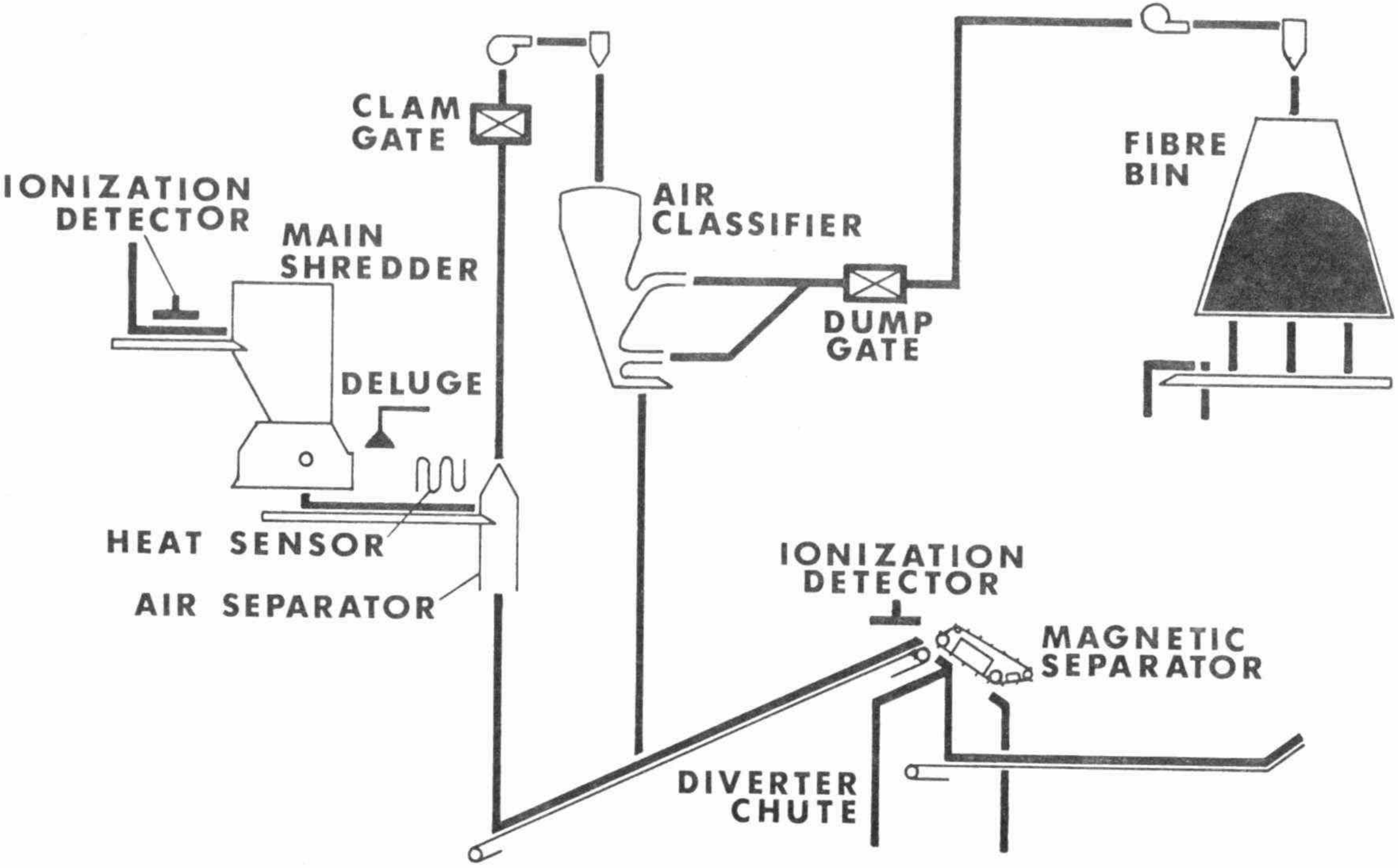

Figure 2 Primary Shredder - Air Separator Original Fire Protection System

5. Operating procedures were designed so that no personnel would be required in the shredding area during operation;
6. One of the exterior walls in the shredder room was equipped with 2.4 x 6.1 metres blowout panels.

In spite of these precautions, four major explosions and two minor explosions took place within the primary shredder during the plant's first two and one-half years of operation. There were no staff injuries encountered in any of the incidents but building and equipment damage totalled approximately $300,000 for the four major incidents. Most of the property loss was due to damaged building siding requiring total replacement.

As part of the original fire control system design, the primary shredder exhaust system and associated baghouse shut down either when the shredder feed conveyor was off or when the overall fire protection system was activated. This mode of operation for the shredder dust control system may have had severe ramifications as discussed later.

Plant modifications and changes in operating procedures arising from experiences with fires and explosions are discussed in a later section.

THE FIRE PROBLEM

Fire Areas

Most of the fires in the Experimental Plant have occurred either in the primary shredder or in the conveyors immediately preceding and following the shredder. Since plant startup, a total of 11 fires have occurred in the receiving and transfer portion of the plant. Of the total of 66 fires in the resource recovery system during the period April 1978 to October 31, 1980 inclusive, 53 fires occurred in the primary shredder, its feed conveyor, or its discharge conveyor. Other areas of fire include the other two shredders, the pneumatic conveying lines, the storage bins, and the conveyors fed from the receiving floor. The fires downstream of the shredders are believed to have originated in the shredders but were not detected or detectable until they manifested themselves elsewhere in the plant. There has been minimal spreading of fire due to waste spillage or dust accumulation, likely because of adequate housekeeping and the localized nature, in general, of fires in the processing line.

The location of fires experienced in the resource recovery system is shown in Table 1. Although individual fires may have also involved areas other than those shown, the principal area of involvement was used to define the fire location.

Fire Incidents

The simplest cause of fires is that the fire existed in the waste load when it arrived at the plant. This was likely the case for the eight fires that were experienced in the receiving area or on the conveyors fed from the receiving floor. In three other cases, the fire was not detected until the waste was loaded into transfer vehicles. Careless disposal of lighted cigarettes is another fire source in the receiving area and is believed to be the cause of at least two other fires. In another case, sparks from the bucket of the front-end loader scraping on the receiving floor ignited butane from containers punctured by the front-end loader.

There appears to be two principal causes of fires experienced in the resource recovery processing system, both due to the shredding operation. Many of the fires experienced after initial plant startup were caused by hot metal objects thrown out of the primary shredder onto material in the shredder feed conveyor when this conveyor was stopped. Combustible material in the conveyor ignited and fire spread rapidly unless quickly detected. Many other fires are believed to have started in the shredder due to friction between the shredder rotor and debris accumulated in certain areas of the shredder. Other fires downstream of the shredders, such as in the pneumatic conveying lines and the storage bins, almost certainly resulted from primary ignition in the shredders.

Damage from the many fires has been relatively minor; in three cases there was damage from the fires themselves and in one of these cases greater damage resulted from water damage from fire fighting activities. The three fires causing physical damage are reviewed in the following in more detail.

One of these fires occurred after operating hours in waste material stored on the receiving floor. While the severity of the fire was minimized by the sprinkler system protecting this area, considerable damage resulted from water erosion of the roadway exiting the receiving floor. Building damage was limited to the loss of several lights and materials to reset the sprinkler system. Total damage was approximately $7,000.

TABLE 1

LOCATION OF FIRES

Equipment	Number of Fires
Primary shredder	25
Primary shredder feed conveyor	17
Primary shredder discharge conveyor	11
Other conveyors	5
Secondary pneumatic system	3
Other shredders	2
Fibre storage bins	3
Total	66

The greatest physical damage to the resource recovery processing line occurred on June 16, 1978. After a feed stoppage, a fire started in material in the vibrating conveyor feeding the primary shredder. The fire was visually detected by operating staff but only after the fire developed sufficiently to involve the belt conveyor feeding the vibrating conveyor. The belt conveyor was burned through, rubber lagging on the head pulley was slightly damaged, a cleaning brush on the conveyor return was destroyed, and rubber skirting near the head pulley was burned. All damage to the belt was limited to an area less than ten feet from the head pulley. Two full production days were lost in replacing approximately fifteen feet of conveyor belting damaged in the fire. Fire fighting activities also necessitated that the plant power supply be shut off for approximately eighty minutes. Waste receipts and other plant operations had to be suspended during this period. Total damage was estimated at $5,000.

The third fire resulting in physical damage occurred in the organic fibre storage bin. Following a long weekend, operating staff discovered a smouldering fire near the bottom of the organic fibre storage bin. Heat from the fire resulted in the loss of a drive motor for a material distribution flinger near the top of the bin. One production day was lost in unloading the bin and extinguishing smouldering or burning material as it was discharged. Total damage was estimated at $1,000.

The remainder of the fires resulted in little or no physical losses. The greatest adverse effect from these fires was the loss of production time. Downtime from the fires has been relatively short for most fires, as illustrated in Table 2.

There were no staff injuries associated with any of the fires.

Fire Fighting Considerations

Most of the fires have been detected and extinguished by operating staff. In fact, the local fire department has only been called by the detection service after an indication of water flow in a sprinkler system or activation of a smoke detector. In most cases, the fire department has not been involved in the actual fire fighting. The involvement of the fire department has usually been after normal operating hours, especially for the fires on the receiving floor.

TABLE 2

DOWNTIME FROM FIRES

Equipment	**Number of Fires in Downtime Intervals (minutes)**						
	0-30	31-60	61-90	91-120	121-150	241-270	480
Primary shredder	12	5	3	0	4	1	0
Primary shredder feed conveyor	9	6	2	0	0	0	0
Primary shredder discharge conveyor	7	1	1	1	2	0	0
Other conveyors	2	0	0	1	0	0	1
Secondary pneumatic system	3	0	0	0	0	0	0
Other shredders	2	0	0	0	0	0	0
Fibre storage bins	2	0	0	0	0	0	1
TOTAL	37	12	6	2	6	1	2

All of the fires have been extinguished with water. The carbon dioxide systems retrofitted for protection of the pneumatic systems and their baghouses have discharged a total of seven times but all of these activations were false.

Apart from the nuisance aspects following a fire, water has been effective as a fire extinguishing agent and is more readily accepted than other extinguishing agents by our insurance underwriters. Nuisance aspects to consider are water damage of stored products or equipment in the lowest building elevations and damage due to freezing during winter operations.

Most fires were ultimately extinguished with hand-held hoses. Sprinkler systems, when activated, have served their intended purpose to contain the fire. A number of the retrofitted water deluge systems have been very effective in providing an immediate response to fires or suspected fires in remote or hazardous areas of the plant. Hand-held hoses then are used to ensure that fires are completely extinguished.

Fire fighting efficiency and loss control have been maximized by keeping the burning material in motion! The only serious damage to the resource recovery processing equipment occurred when the waste material was stationary. Normal fire fighting procedures are to keep burning materials on a conveyor in motion past a deluge nozzle or a stationary member of a fire fighting crew. Conveyor speeds are such that the burden on the conveyor can be effectively wetted prior to discharge out of the building in the fire dump chute. The whole belt conveyor is also wetted in this process, ensuring that it will not ingnite.

The need for effective training of personnel and the rapid response to fires has been demonstrated in the ERRP. The virtually automatic response of staff to fires has undoubtedly accounted for the minimal damage from the large number of fires. It is essential that fire fighting crews be familiar with the plant layout and any hazards. This familiarity should be extended to local fire department crews through site visits.

Care must be taken to ensure that automatic detection systems are maintained and that ineffective equipment be replaced or deleted so that alarms are not ignored because of a previous history of false alarms. Similar care must be taken in notifying a security service if plant maintenance activities, such as welding near smoke detectors or shutting off a water main, are likely to result in an alarm indication.

Fire Loss Control System Modifications

Many of the fires experienced in the resource recovery processing system during initial plant startup could have been prevented or more readily controlled with the fire protection systems now in use. Modifications to the original design include both operating procedures and the addition of fire protection equipment.

The large number of fires experienced in the shredders and the difficulty and hazards of fighting a fire in enclosed conveyors in close proximity to the shredders led to the installation of a water deluge system above the enclosed vibrating conveyors feeding the primary and secondary shredders. Material on these conveyors is rapidly wetted when the deluge solenoid is activated in the local area or by the process operator at the control panel. The features of the deluge system are as follows:

1. Operator response to the detection of smoke or fire in the shredder area is immediate;
2. A small water volume quickly applied has proven effective;
3. The slight decline of the shredder feed conveyor serves to drain the water into the shredder where it is effectively dispersed by the rotor wetting material in the shredder;
4. Water damage and subsequent cleanup activities are minimized because water is contained within the processing line;
5. The possibility of staff injuries is minimized by reducing the need to use hand-held hoses.

The effectiveness of the water deluge system for the shredders has led to the installation of a water deluge system over the belt conveyor receiving material discharged from the primary shredder discharge conveyor and the air separation system. This system has been effective when used in combination with the early detection provided by the closed circuit television system or the shredder discharge conveyor heat detector.

Following fires in the secondary pneumatic system and the two fibre storage bins, additional fire protection systems were installed for the air separation systems. Fires in the bins resulted in little physical damage but the potential for major damage in the absence of any automatic extinguishing system was illustrated. Following a review of a number of alternatives and combination of alternatives, including different extinguishing agents and their use in different areas, it was decided to install a carbon dioxide system for each of the two pneumatic conveying systems and their baghouses. Upon activation, carbon dioxide is discharged into the pneumatic conveying line and the baghouse simultaneously with the shutdown of fans and closure of dampers past the fans and at the baghouse discharge. These systems have activated seven times with no evidence of fire, likely because of mechanical triggering of the heat detector. An alternative type of detector has been installed; one false activation has occurred with the new triggering mechanism in one year of operation compared to six false activations in the previous eight months. The baghouses, located outside of the building, are also protected by a dry sprinkler system. The storage bins receiving material from each of the pneumatic systems were also retrofitted with sprinklers.

Because of low ambient temperatures in several plant areas during winter operations, the original wet sprinkler systems were converted to dry sprinkler systems. Some problems have been experienced with these systems during the winter because of residual water freezing, splitting piping, and activating the system. Thorough drainage of the piping has been difficult. Ionization type smoke detectors located near processing equipment have been ineffective because of activation by dust and are no longer in service.

The diverter gate system used to discharge burning material from a belt conveyor to the outside was found to have a fundamental flaw. The diverter gate is operated by plant compressed air; however, there was no alarm signal to indicate the loss of air pressure sufficient to operate the diverter gate. An alarm has since been installed. Fortunately, this oversight was discovered during a check of the controls rather than during a fire. The dependence of any fire protection system upon other plant services, such as air or electricity, should be considered. Plant staff must be prepared to revert exclusively to hand-held hoses if loss of a service disables a more sophisticated system.

The screening of the waste by manual inspection has been recently given greater emphasis, primarily as the result of the first three explosions in the primary shredder. Hazardous materials which could result in fires or explosions are routinely removed from the processing line. However, such screening is not expected to be totally effective because the feed rate and the burden depth on feed conveyors precludes detection of all hazardous materials.

A modification to the primary shredder late in June, 1979 appears to have been effective in preventing fires; even with a substantial increase in production during July, 1979, there were no fires. The addition of a series of weld beads at an angle on the edge of the rotor end discs serves as a fan to keep certain areas of the shredder swept clear of accumulations of debris which are believed to have been the source of many fires. It is believed that such debris was ignited due to friction.

There was a sudden increase in the number of fires (six) in the resource recovery facilities during May, 1980. The weld beads on the rotor end discs were found to be considerably worn since their initial installation in June, 1979 and were restored. There was only one fire in the next three months and this one was caused by hot metal being thrown out of the shredder into debris in the explosion vent.

While problems or deficiencies or both have been encountered with some of the fire protection equipment, such has not been the case with plant operating personnel. Plant personnel have been trained in fire fighting techniques and have repeatedly demonstrated the value of this training in responding quickly and effectively to fires. In many cases, when activation of a sprinkler system results in response by the local fire department, the fire has been extinquished by plant personnel and action has been taken to restart waste processing before the fire department arrives. It is considered essential that plant management staff and senior production personnel receive training in fire fighting and loss control techniques.

THE EXPLOSION PROBLEM

Since plant startup in April 1978 to October, 1980, seven explosions have been experienced in the resource recovery processing system. The first explosion occurred in the secondary shredder and the remaining six occurred in the primary shredder. Physical damage resulted only from explosions in the primary shredder.

December 4, 1978; PM

The explosion in the secondary shredder occurred shortly after feed to the shredder had been stopped to clear a material jam in the feed hood. No damage resulted from this small explosion. A solvent is suspected as the source of the explosion; paint containers were found in material removed from the shredder during the inspection for damage.

December 21, 1978; AM

Shortly after plant operations had started, an explosion occurred either in the primary shredder or the shredder feed conveyor or both after material feed was resumed following the clearing of a jam in the shredder discharge conveyor. An employee in the building at the time of the explosion suffered no physical injury and recovered quickly from the temporary shock of the incident. This was the first explosion resulting in extensive physical damage. Fires resulting from the explosion were extinguished by plant staff and the local fire department.

Most of the damage was to the buildings rather than the shredder or adjacent processing line equipment; however, the baghouse associated with the dust collection system for the shredder feed conveyors suffered extensive damage. All exterior siding on the shredder building was either blown off (on the shredder feed side) or loosened (on the shredder discharge side) and was ultimately replaced. Interior siding enclosing the shredder room was loosened or bent. The blowout panels in the side of the building were blown out and broke off of their attached restraining chains; however, the explosion doors on the primary shredder did not open. Some siding on two adjacent, attached buildings was either loosened or blown off. The baghouse serving to collect dust from two conveyor transfer points, one of these being at the shredder feed conveyor, suffered a coincident or secondary explosion. The dust hopper at the bottom of the baghouse was distorted and the dust discharge screw conveyor bent. Most of the baghouse bags were destroyed by fire and many of the outlet air venturis were melted. This baghouse was protected by a sprinkler system which was activated but not in time to prevent damage to the bags and venturis. If protection of the baghouse interior as well as the baghouse structure is necessary, a detector with a faster response time than that provided by the sprinkler heads would be required. Dust collection ducting connected to the shredder feed conveyor enclosure was blown off at its attachment flange. An access door to this same enclosure was blown off of its hinges. The building roof was later found to leak from the explosion effects and had to be repaired. There was no damage to the building structural steel. Until the building was repaired, additional minor damage occurred as a result of freezing water lines. Total damage was approximately $110,000; $90,000 due to building damage and $20,000 due to baghouse damage. Building damage from this explosion is shown in Figure 3.

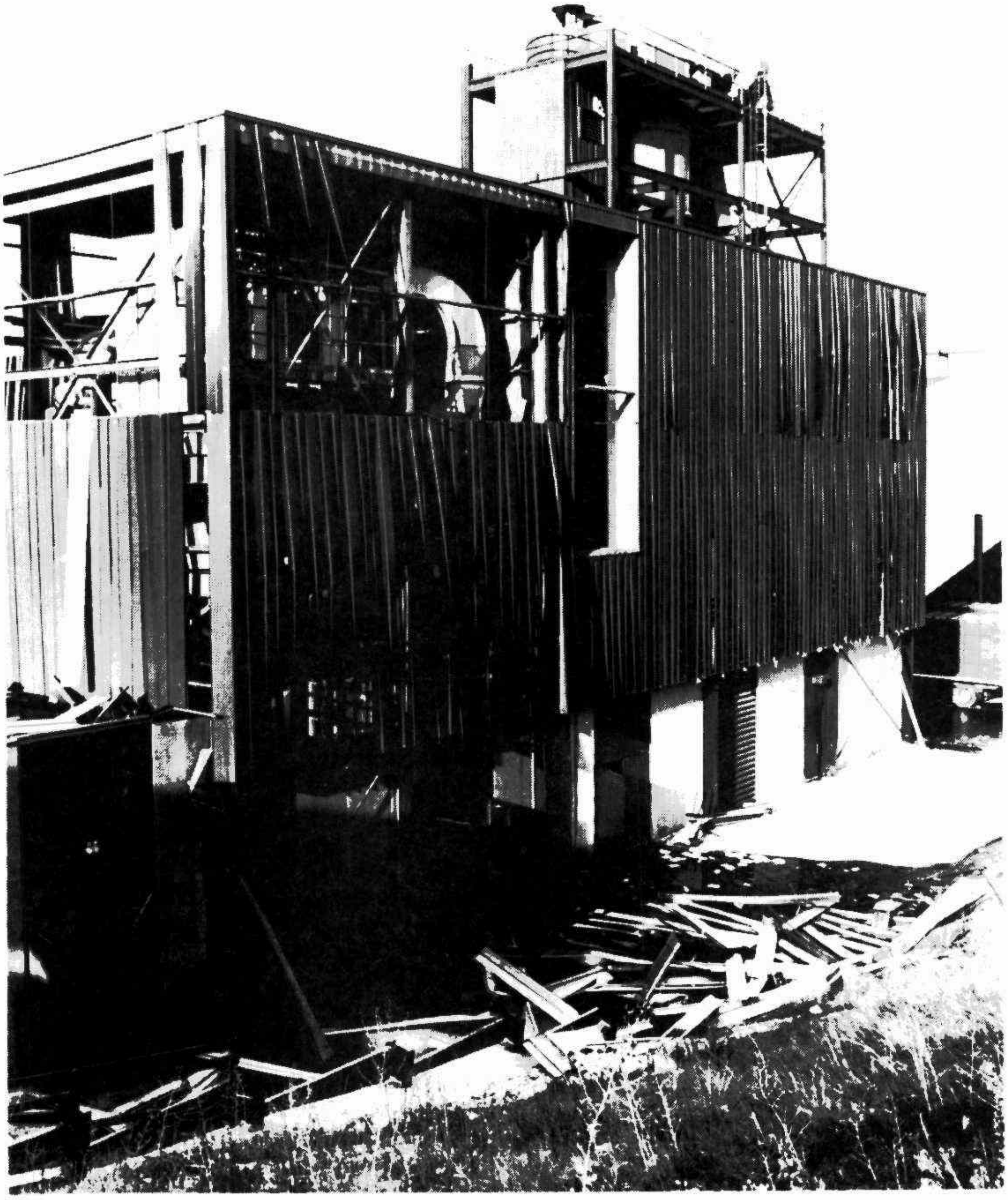

Figure 3 Explosion Damage December 21, 1978

Except for the baghouse, the resource recovery processing equipment remained operational. Although waste was processed on the sixth operating day after the explosion, a total of twenty-one production days were lost as a result of the explosion. The lost production time resulted from scheduled downtime to permit repairs to the building and from impractical operating conditions - wastes repeatedly froze to the steel vibrating conveyor feeding the shredder. Normal plant operations resumed on January 31, 1979. All of the building damage was repaired by this time.

March 29, 1979; PM

A second explosion in the primary shredder resulted in damage to the buildings similar to that from the explosion on December 21, 1978 but was less severe. As examples, the explosion relief panels were loosened slightly out of position but were retained by their restraining chains and the door on the shredder feed conveyor enclosure was only blown open and bent rather than blown off. Again, the explosion doors on the primary shredder did not open. Minor fires following the explosion were extinquished by plant staff before the local fire department arrived. There was no damage to the baghouse but a strong solvent odour was detected in the baghouse following the explosion. There were no staff injuries resulting from this explosion. The processing system suffered no damage. The following day had been previously scheduled as downtime for maintenance and on the next operating day normal operations resumed. Total damage was estimated at $50,000. Building damage is illustrated in Figure 4.

April 19, 1979, PM

The third and most severe explosion to this time also occurred in the primary shredder. Damage from the explosion on March 29 had not yet been repaired so that the damage sustained added to the existing condition. There was further damage to the building, much of the siding previously loosened was blown off and more siding was loosened. The building explosion relief panels were blown completely out, again breaking free of their restraining chains. For the first time, the explosion relief doors on the side of the shredder were blown open; one door was bent from striking the feed hood at the end of its swing. Again the dust collection ducting and the access door on the shredder feed conveyor enclosure were blown off. This time, however, the enclosure was distorted and many of the edge welds on the 9.5 mm steel plate were split apart. One of the belt conveyor frames was momentarily spread apart allowing the

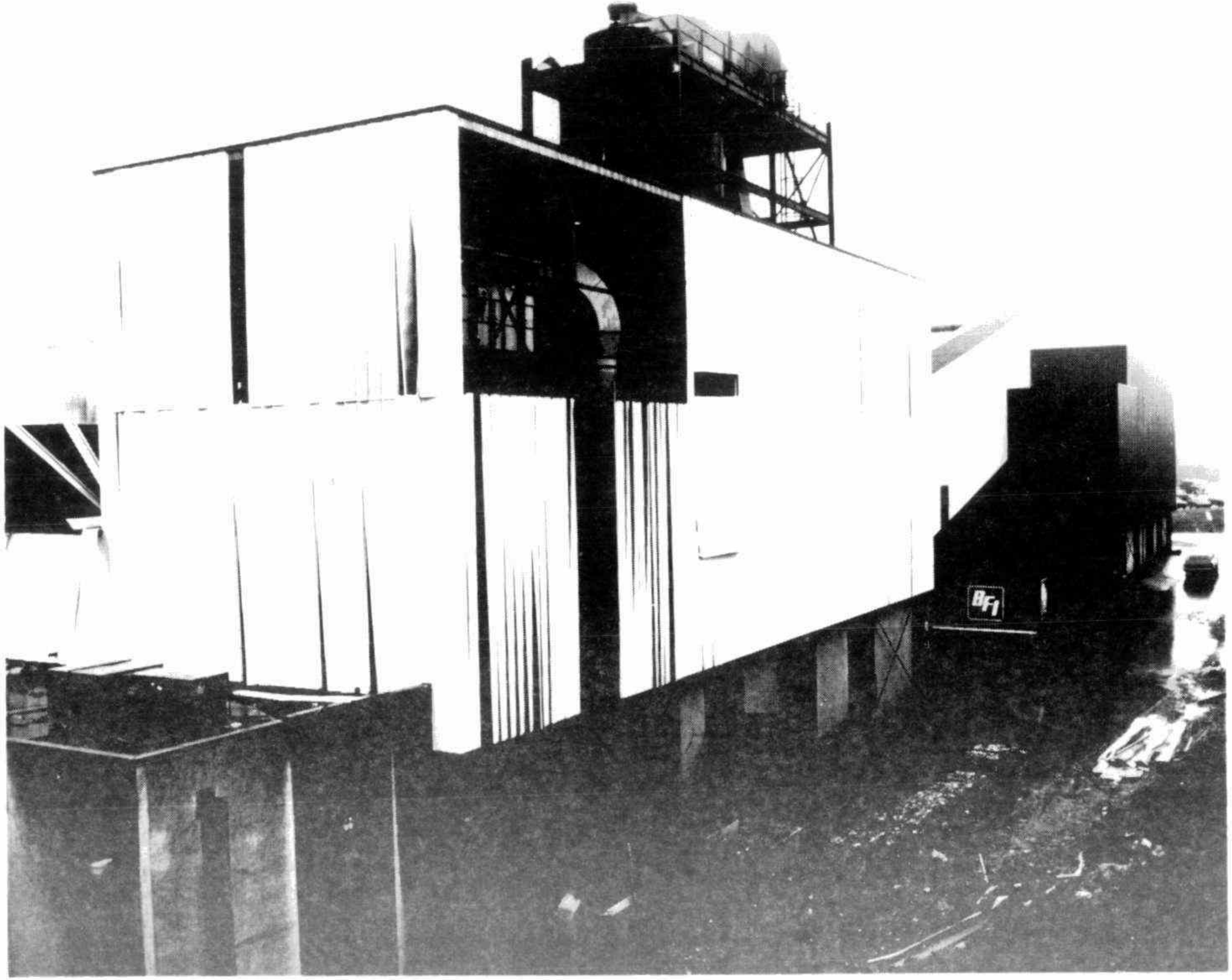

Figure 4 Explosion Damage March 29, 1979

idlers to fall out of position. Parts of the air separator at the end of the shredder discharge conveyor were distorted. A glass door in a fire hose cabinet approximately 18 metres from the shredder was shattered. The shock of the explosion was felt in a Ministry office building approximately one kilometre away.

This explosion was believed to have originated lower in the shredder than the two previous explosions. The baghouse was not affected and there were no fires of sufficient size to set off any of the sprinkler systems. Plant staff extinguished the minor fires. There were no staff injuries. Damage from this explosion was estimated at approximately $90,000 in addition to the damage from the March 29 explosion. Building damage is illustrated in Figure 5.

Following this explosion, normal operations did not resume again until May 22, 1979. Although the processing equipment was operational soon after the explosion, no attempt was made at further operation until a course of future loss control measures had been established and these measures confirmed to the satisfaction of the Ministry's insurance underwriters.

December 6, 1979, AM

The fourth explosion in the primary shredder was more severe than the previous three as evidenced by the damage to the process equipment. Building siding damaged in the third explosion was being replaced at the time of this incident. New siding on the enclosure above the belt conveyor feeding the shredder was blown off and required replacement. New siding in the shredder building was moved out slightly in several areas but very little siding required total replacement. Siding on adjacent buildings was loosened and had to be reattached. Vents had been installed on the primary shredder prior to this incident and the pressure release afforded by the vents likely accounted for the minimal siding damage in spite of force of the explosion.

The force of the explosion was sufficient to bend outward the sides of the shredder discharge conveyor, a steel pan vibrating conveyor. The bottom of the primary air separator was also distorted; edge welds on the lower rectangular section were split, access hatches were blown off, and bolts on a wear plate prior to the transition to the round section were sheared off. A plastic window on an upper level of the adjacent air classifier was expanded outward and cracked. The air dump clams above the venturi were bent open. Idlers on the lower part of the belt conveyor fed by the shredder discharge conveyor were loosened out of

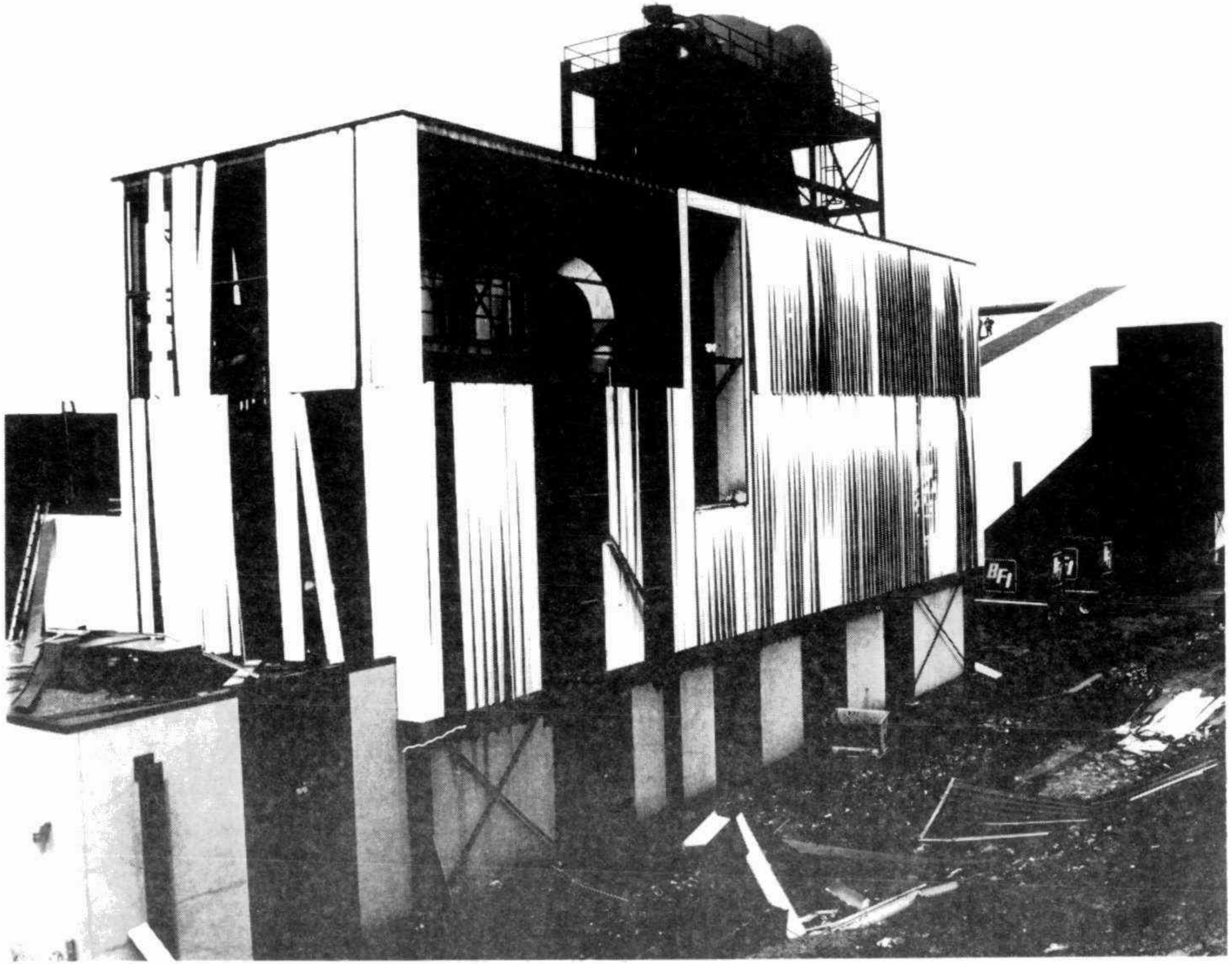

Figure 5 Explosion Damage April 19, 1979

position. The air exhaust duct on the shredder feed vent was blown apart. Both shredder vents were moved slightly out of position but suffered only minor damage.

The baghouse serving to exhaust the shredder feed vent was damaged by a fire and also the force from the explosion. Most of the bags were burned although the air outlet venturis were not damaged as in the December 21, 1978 incident. The bottom of the baghouse was distorted but the screw conveyor was not damaged. Building damage is illustrated in Figure 6.

As in previous explosions there were no personal injuries from this incident.

The cause of the explosion is believed to be an organic solvent. There was a strong solvent odour in adjacent buildings following the explosion and solvent soaked rags were found in the area of the primary air separator.

Damage from this explosion was approximately $35,000. Repairs of the explosion damage started immediately after the incident and the plant resumed operation on December 27. Outstanding siding repairs from the explosion on April 19 were also completed during the shutdown.

April 29, 1980

The fifth explosion in the primary shredder was a minor incident which manifested itself primarily as a fire. The principal evidence that an explosion had occurred was that the plastic vent covering on the shredder feed explosion vent was blown out; the only damage was to the vent covering. The fire associated with this incident was extinquished with no resulting damage. The cause of this explosion was believed to be paint thinner; paint cans were found in the area after the explosion.

May 15, 1980

The sixth explosion in the primary shredder was also a minor incident and most of the damage resulted from the accompanying fire. The processing line had stopped temporarily to permit removal of a heavy piece of metal from the secondary shredder. A fire was then detected on the belt conveyor which feeds the primary shredder. When the conveyors were started to move burning material under the deluge system of the primary shredder feed conveyor, an explosion occurred in the shredder. A fire on the shredder discharge conveyors

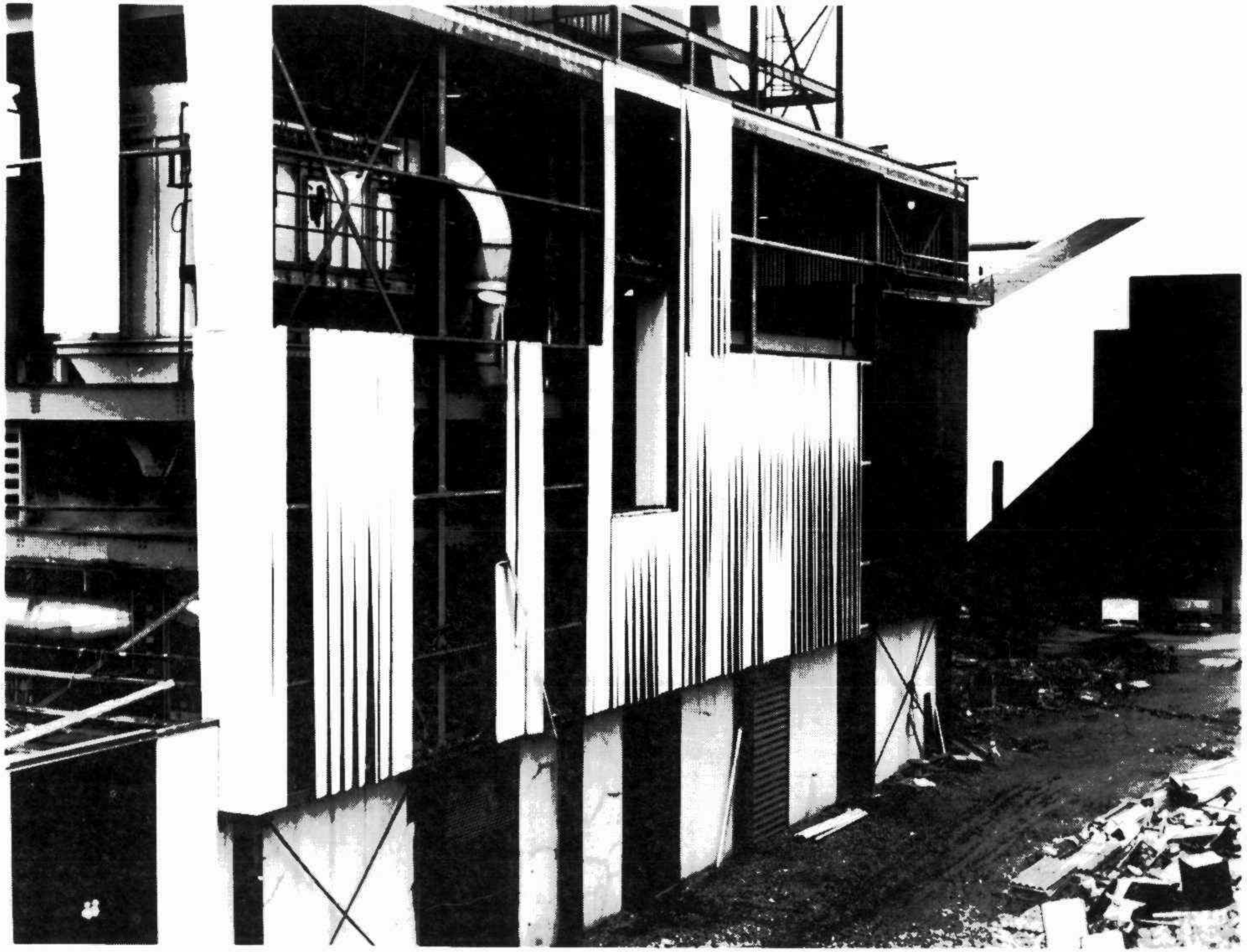

Figure 6 Explosion Damage December 6, 1979

was contained and extinquished by the deluge system and hand-held hoses. Another fire in the baghouse resulted in the loss of 56 of the 150 bags; the baghouse sprinkler system was set off, containing the fire and saving most of the bags. The vent covering on the shredder feed vent was again blown out. The cause of this explosion is unknown. Damage from this incident totalled $2500.

Common Aspects

One of the most fortunate common aspects of the explosions is that no personal injuries resulted. The potential for injuries decreased following each major explosion because of further restrictions on personnel entering the shredder building during operation and changes in operating procedures even when material feed to the shredder has stopped. Now the shredder is stopped if personnel must work in the vicinity of the shredder feed conveyor in order to free a material jam; originally this was not the case primarily because the potential dangers were not fully appreciated. Such changes have not adversely affected production.

Five of the seven explosions are believed to have been caused by volatile organics. It is interesting to note that all four major explosions in the primary shredder occurred on a Thursday. Loads received prior to two of the explosions were traced to a common source generating hazardous material. Such flammable materials are prohibited from disposal at the Experimental Plant. Following the second explosion, a notice was issued to all private haulers as a reminder of the restrictions on waste receipts; compliance with such restrictions depends on the waste generator as well as the hauler.

The first explosion in the primary shredder was considered an unusual event. No action beyond restoring the plant to full operating conditions and a review of waste inspection procedures prior to feeding to the shredder were considered warranted. However, after the second explosion, a number of studies were started. Waste inspection procedures were again reviewed and all waste entering the shredder during a one week period was intensively monitored. All potentially hazardous items (visually detected) were removed from the waste stream. This study indicated that many of these items, such as solvent containers, could be removed without adversely affecting production. However, it also illustrated that in receiving primarily commercial and industrial wastes a large number of potentially hazardous materials are received and that many such items can not be detected in the waste burden on conveyors. To improve the likelihood of detecting hazardous materials, the number of inspectors was increased from two to three. All three of these employees are also engaged in corrugated cardboard recovery.

Following the second explosion in the primary shredder, it was evident that additional loss control measures were required. Consequently, the services of two consulting firms were retained to provide recommendations for lower cost replacement siding for the shredder building and to make recommendations regarding explosion venting, explosion suppression, or other similar action to minimize damage in the event of a future explosion. The third explosion occurred before recommendations for additional loss control measures were received. However, this explosion influenced the design of the loss control systems ultimately installed.

LOSS CONTROL MEASURES

Investigations

The first major explosion in December 1978 was considered to be a serious but isolated incident. The following explosion in March 1979 firmly established the need for additional loss control measures within the plant. Since hydrocarbons and dust were considered to be possible causes of the explosions experienced, additional technical information was required in both of these areas.

The consulting engineering firm originally responsible for plant design and construction project management was engaged to provide recommendations on explosion loss control measures and on building siding alternatives with lower replacement cost. The study recommended that shredder venting be the prime method of explosion protection. Shredder venting was possible at three locations: feed opening, explosion doors opening, and at the open end of the shredder discharge conveyor. Because of the interior location of the shredder as well as the location of ancillary equipment, it was only practicable to provide venting at the first two locations, that is, the feed opening and the opening remaining from removal of the original shredder explosion doors. On the question of building siding, a commonly available siding was chosen as opposed to the original siding available only from a single supplier. In addition, the use of 2.4 m long siding was recommended as opposed to the previous 10.7 m lengths. One disadvantage of the use of long siding was that damages arising from building overpressures invariably resulted in damage to the entire section of siding thus necessitating total replacement. With shorter siding sections, siding damage might have been contained within a smaller surface area. Although only a portion of the new siding had been installed at the time of the December 6, 1979 explosion, this benefit of the smaller siding was evident.

A second consulting firm specializing in fire and explosion loss control studies was engaged to review plant facilities and operating procedures in the primary shredding area and make recommendations on loss control measures that the Ministry could further undertake. This work resulted in recommendations involving shredder venting, additional personnel protection, and the consideration of suppression devices in key areas such as the baghouse serving the primary shredder and at the opening where material entered the shredder feed system. They also recommended that the baghouse discharge be redirected outside and that the dust collection system continue to operate for at least 5 minutes after the conveyors shut down. The use of an explosion suppression system for the primary shredder was considered but rejected for the same reasons for not installing such a system originally; that is, the high cost and the limited effectiveness over the range of potential explosion sources which could be encountered in waste receipts. A company providing explosion suppression devices recommended against a system protecting only key areas such as the baghouse; such a system was recommended only as a part of complete suppression system protecting the shredder.

Since volatile organics were suspected as the cause of at least two major explosions, it was decided to monitor total hydrocarbon concentrations in the shredder exhaust air continuously for several working days. The hydrocarbon monitoring system used an IPM Model RS5 total hydrocarbon analyzer, with a flame ionization detector operating over a measuring range of 0 to 10,000 ppm, with concentration values presented as methane equivalent. The sampling point for most of the work was located in the shredder feed duct approximately 3 m from the shredder feed opening itself. This sampling location yielded hydrocarbon concentrations present in the exhaust air, normally moving at 2.6 m^3/sec.

Hydrocarbon monitoring was carried out during the processing of refuse with the normally high commercial-industrial mix and during one day when residential refuse was processed exclusively. Major differences were observed between the number and size of hydrocarbon peaks measured during the processing of residential waste as compared with the industrial refuse. Typical recorder traces of these results are presented in Figures 7 and 8 for commercial and residential waste processing respectively. The difference in the frequency and magnitude of peaks for each type of waste can be seen in these traces and is further summarized in Figures 9 and 10.

The most outstanding feature of the results was the hydrocarbon concentration differences observed when processing residential as opposed to industrial refuse. The highest peak measured for residential waste was 9,600 ppm while it is estimated that some of the peaks during the processing of industrial refuse reached a concentration of 20,000 ppm. When processing residential waste, the peaks were generally less than 3,000 ppm while hydrocarbon peaks associated with industrial waste processing ranged from 2,000 to 10,000 ppm including numerous occasions when readings were off-scale.

Close examination of the concentration traces indicated that there was considerable difference in hydrocarbon concentrations over short time periods, likely reflecting the varying contents of different truck loads of refuse.

The hydrocarbon concentrations discussed above are considerably lower than the lower flammability limits for hydrocarbons, generally in the range of 50,000 ppm to 80,000 ppm (as methane equivalent). However, it is conceivable that these flammable concentrations could be reached at some localized points within the shredder system, particularly if the shredder exhaust air of 2.6 m^3/sec were curtailed. The original plant operating procedures may have unwittingly allowed the establishment of explosive concentrations of hydrocarbons. The original system design called for the shredder exhaust fan to be off when the vibrating conveyor feeding the shredder was also off. In view of the results of the hydrocarbon monitoring, this procedure could have given rise to localized concentrations of hydrocarbons exceeding the lower explosive limits. After the third major explosion, the shredder exhaust fan was set up to operate continuously, shutting down only when the major fire control system was activated. For a shredding system without forced ventilation, it would appear very probable that hydrocarbon concentrations in the explosive range could readily be attained. When the shredder explosion vents were installed, the volume of air withdrawn by the shredder exhaust system was increased. This air, withdrawn from the shredder feed vent, was redirected outside the building from the baghouse discharge to preclude a build-up of potentially explosive gases within the shredder building. This action had been recommended by the loss control consultant.

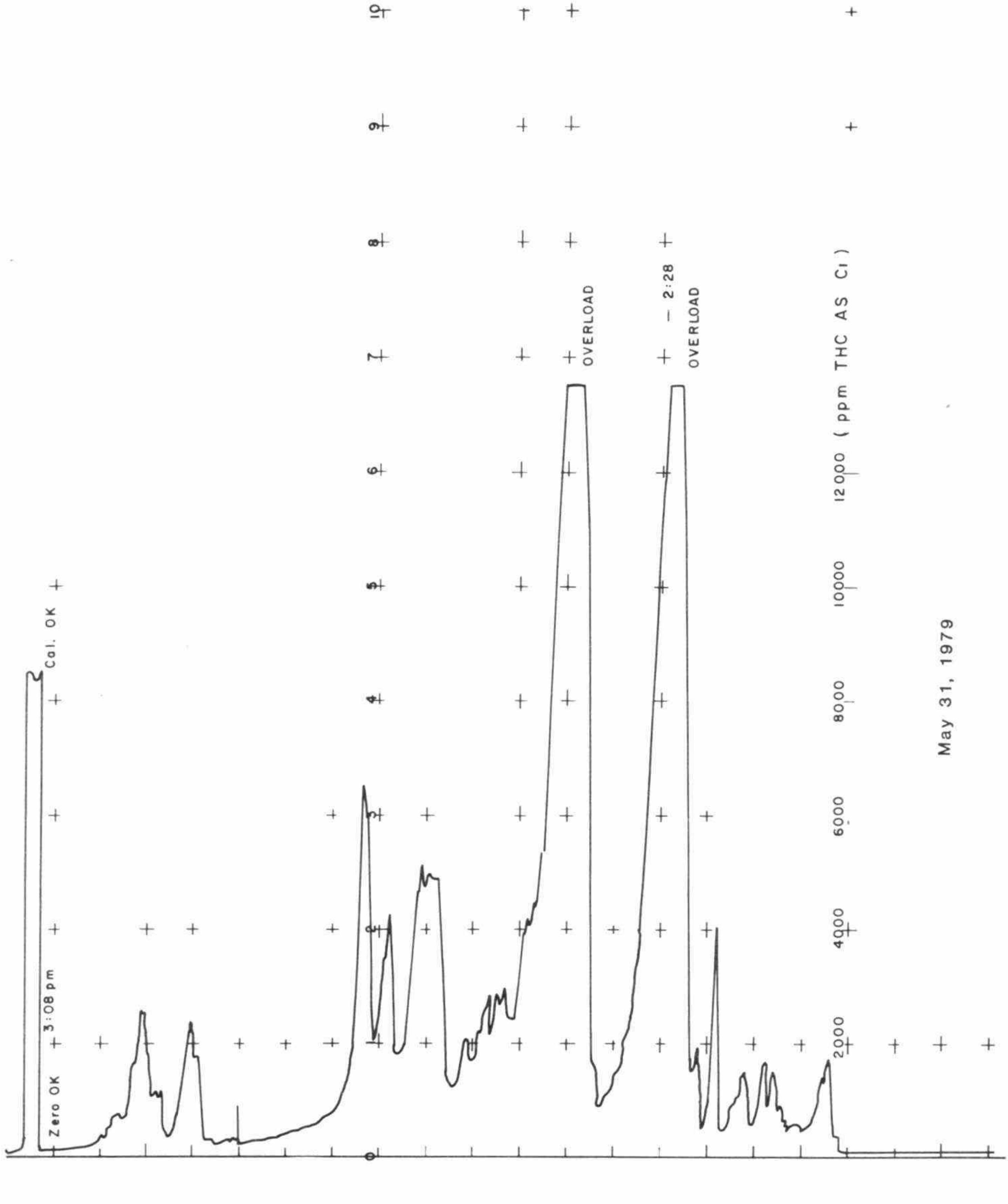

Figure 7 Hydrocarbon Concentration in Shredder Feed Area – Commercial Waste

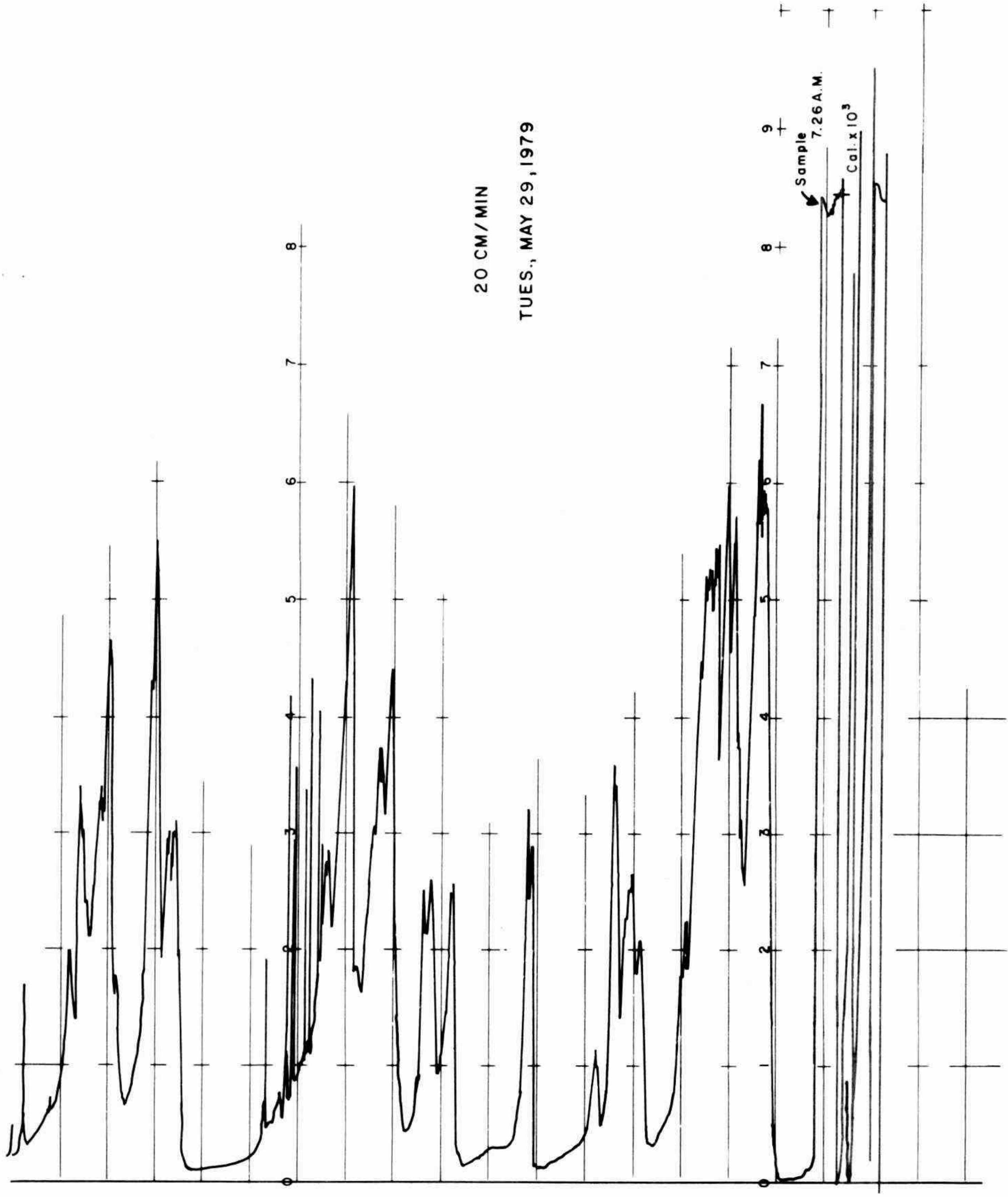

Figure 8 Hydrocarbon Concentration in Shredder Feed Area – Residential Waste

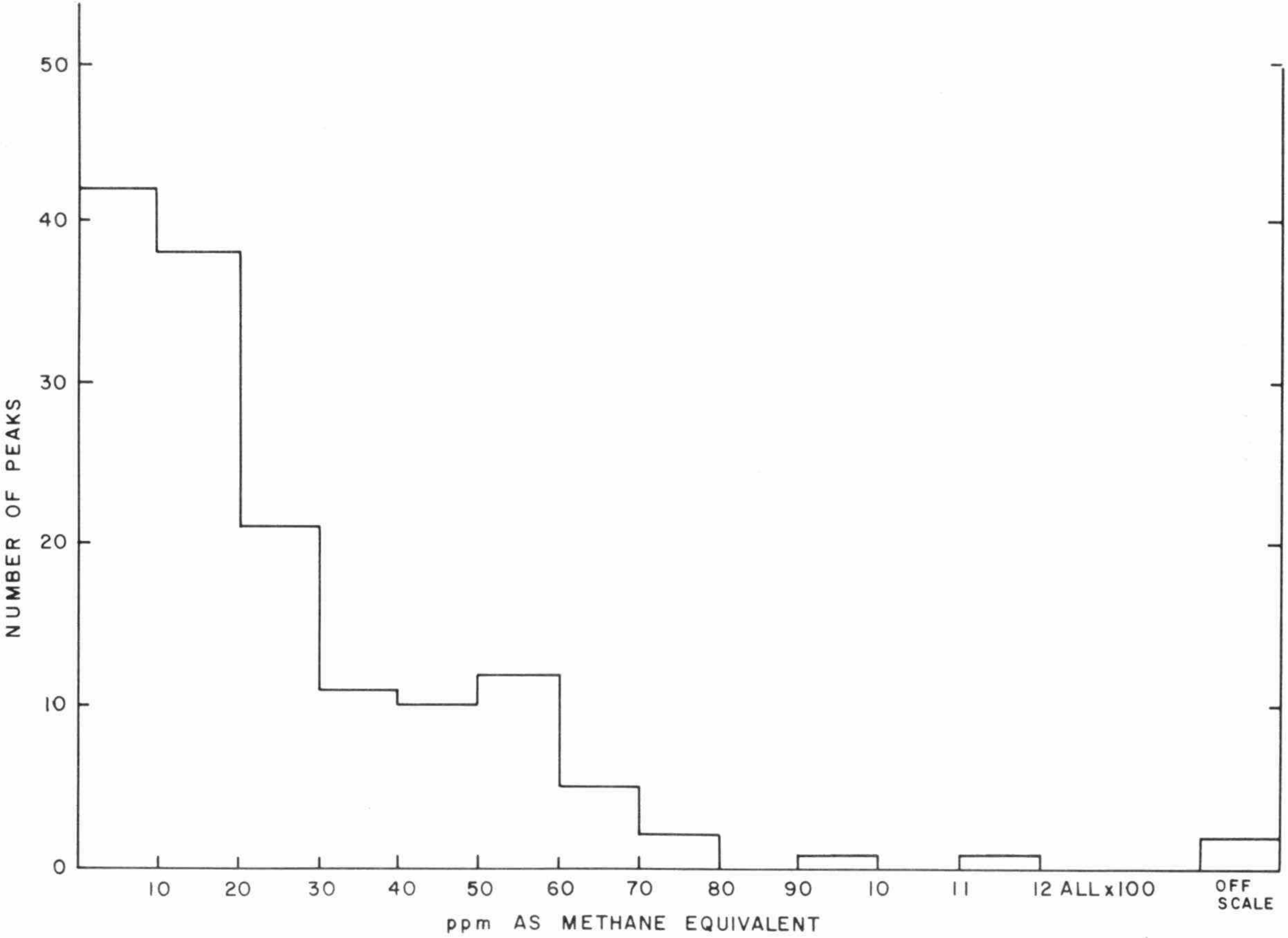

Figure 9 Histogram of Hydrocarbon Peaks - Commercial Waste - May 31, 1979

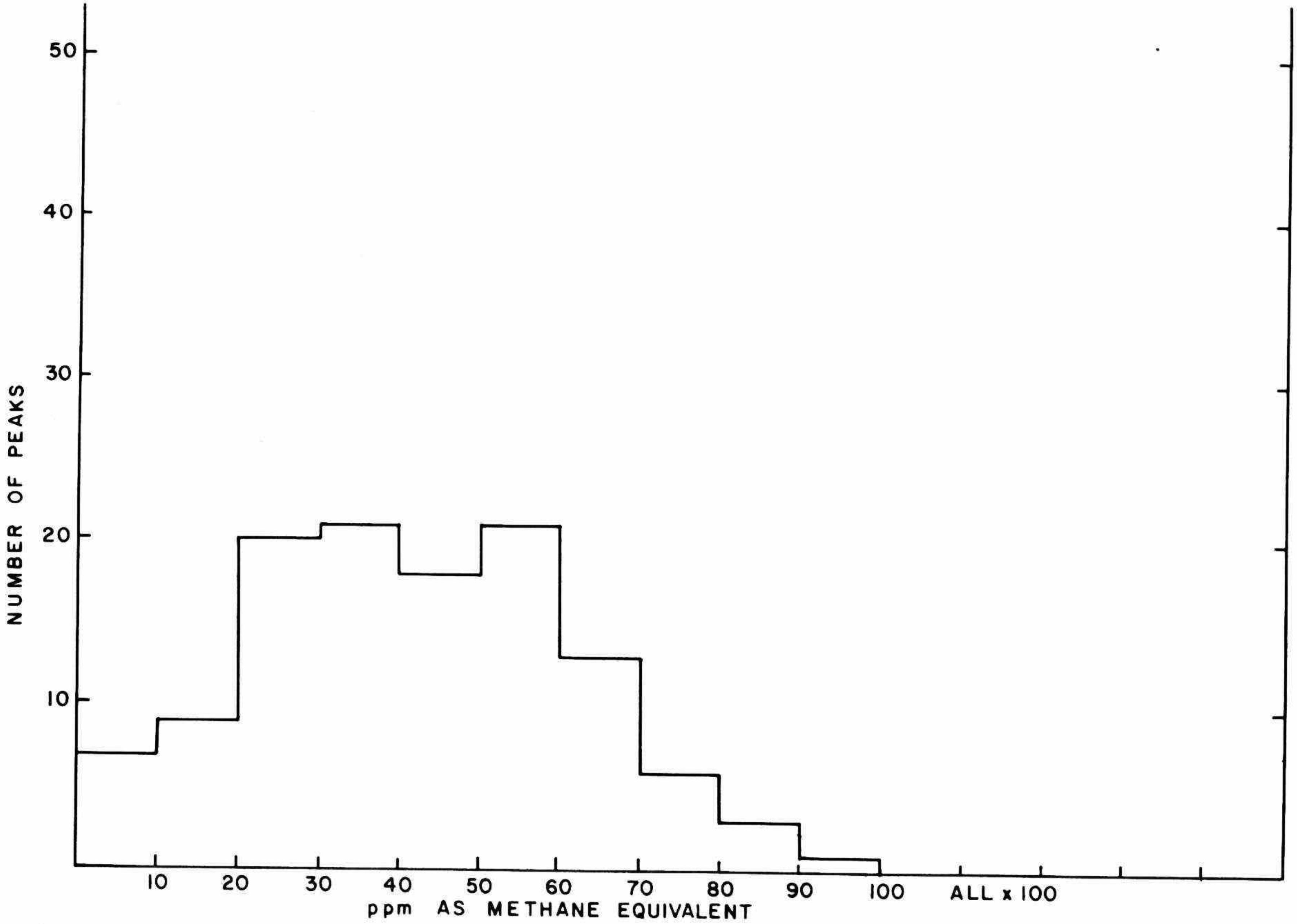

Figure 10 Histogram of Hydrocarbon Peaks - Residential Waste - May 29, 1979

As there had been some speculation as to whether the baghouse damage from the first explosion was associated with a secondary dust explosion, sampling and analyses were carried out on dust collected by the shredder exhaust baghouse. Dust production during processing periods was estimated by collecting the baghouse dust produced during a processing shift on several days. These limited data indicated a mean dust production rate in the range of 14 to 28 kg/hr. Obviously such a mean determination does not preclude the possibility of much higher instantaneous or short term dust concentrations which may be associated with a particular type of industrial waste. However, it was felt that such work could at least yield some qualitative information on the characteristics of dust associated with the shredding of refuse.

Generally, dust is considered to be capable of forming explosive concentrations only when a sufficient quantity of the dust particles present are below a maximum size of 40 mesh (420 um) (3). The dust samples obtained from the primary shredder baghouse were analyzed for particle size distribution and volatile matter content. The results indicated that approximately 33% of the total dust produced was in the size range capable of causing explosions and that this material as a whole contains 75% volatile matter. The mean explosive dust concentration can be then calculated using the total dust generation rate, percentage in the explosive size range, volatile content, and air flow rate. Realizing the extremely gross nature of these calculations, it can be estimated that the mean explosive dust concentrations were in the order of 3.8×10^{-4} to 7.5×10^{-4} kg/m^3, a figure well below the minimum explosive concentration of 0.1 kg/m^3 indicated in reference 3. Again, extreme situations in the type of waste being processed, coupled with localized conditions could yield much higher dust concentrations but the above data appear to indicate that the possibility of dust explosions in shredding solid wastes is somewhat remote. Considering that these data were generated from the processing of commercial-industrial waste, which generally has a lower moisture content than residential waste and likely to result in higher dust generation rates than municipal refuse, the possibility of a dust explosion from shredding municipal wastes appears minimal.

There is a possibility of synergistic effects from a hybrid mixture of dust and volatile organics but the lack of practical information in this area precludes action based on these considerations.

Plant Modifications

Modifications to the fire protection systems were discussed in the section, "THE FIRE PROBLEM".

The major modification undertaken as a result of the explosion investigations was the provision of venting for the primary shredder. The shredder vent areas, duct sizes, ultimate vent openings and duct design were taken from the consultant's recommendations.

Plan and section views of the explosion venting ducts are shown in Figures 11 and 12. In general, the shredder vent areas, duct sizes, and ultimate duct openings were calculated in accordance with the NFPA guidelines for explosion venting (3). As these guidelines indicated that overpressures of 14 to 21 kPa could be expected with the vent areas provided for the given shredder volume, vent ducts were designed to withstand 21 kPa overpressure. Because of the vent lengths required to the outside walls, the vents were designed with increasing cross-sectional area to compensate for the length. A pressure transducer has been installed in a vent to record maximum pressure in the event of a future explosion.

As indicated earlier, a readily available building siding was chosen to be installed in 2.4 m lengths. In the event of a further incident, it was felt that siding destruction might not be so total as with the 10.7 m long siding used previously. The siding fastening was designed to yield at approximately 0.72 kPa

Metal detectors have been installed within the plant for detection of hazardous or nonprocessable metal items. The one of most interest is located on the belt conveyor bringing material to the primary shredder feed system. Although a detailed study of this application has not been made yet, preliminary results are encouraging with respect to this approach.

The underwriters insuring the facility against both liability and loss damage became increasingly concerned with each explosion. After the third explosion, resumption of normal plant operation was delayed until the underwriters were collectively assured that there was indeed an awareness of the seriousness of these incidents and that the Ministry was undertaking loss control measures considered to reflect the best state of the art at the present time. The property damage deductible rose from the general \$2,500 figure for damage anywhere within the facility to \$100,000 deductible for explosions in the primary shredding

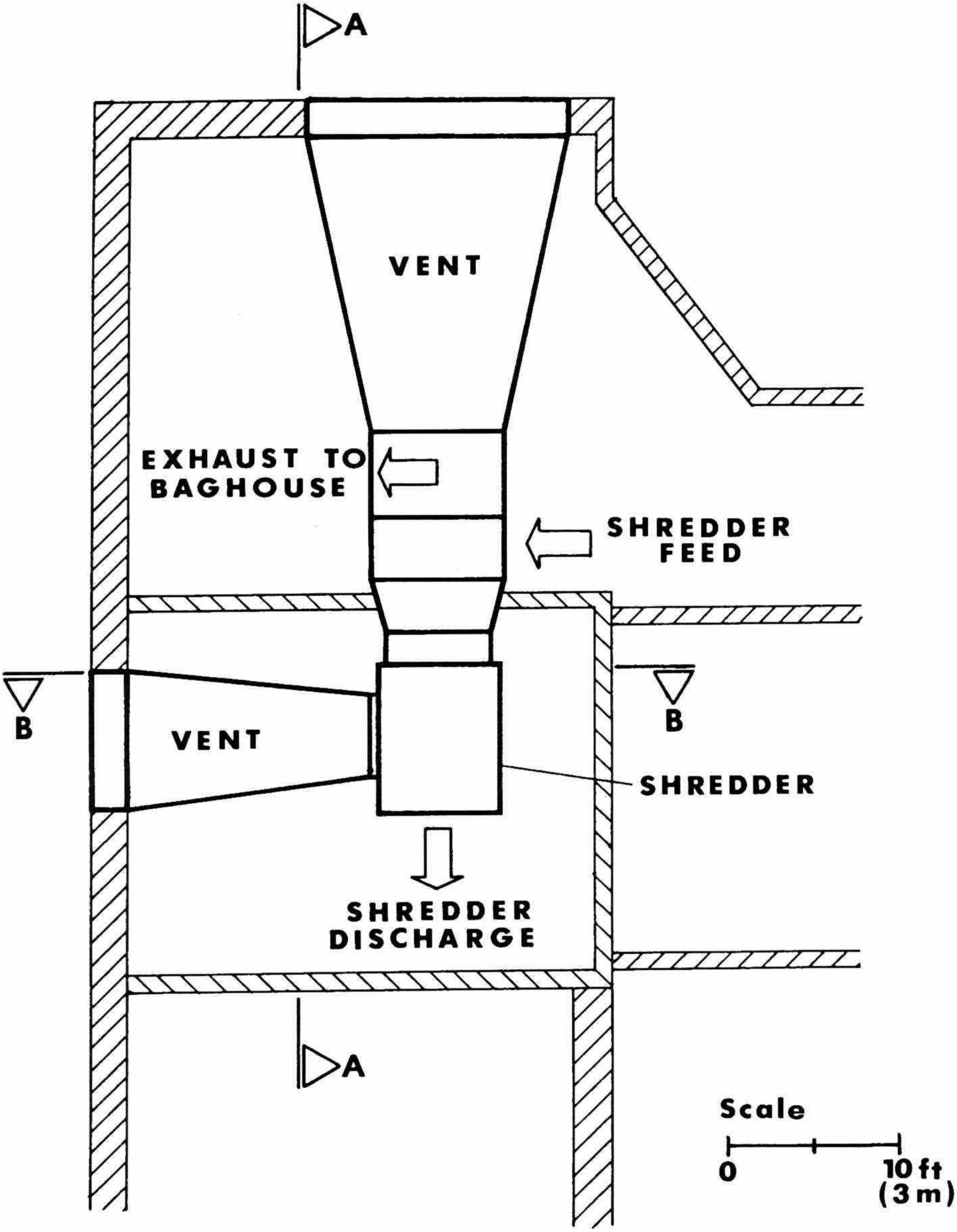

Figure 11 Primary Shredder Venting (Plan)

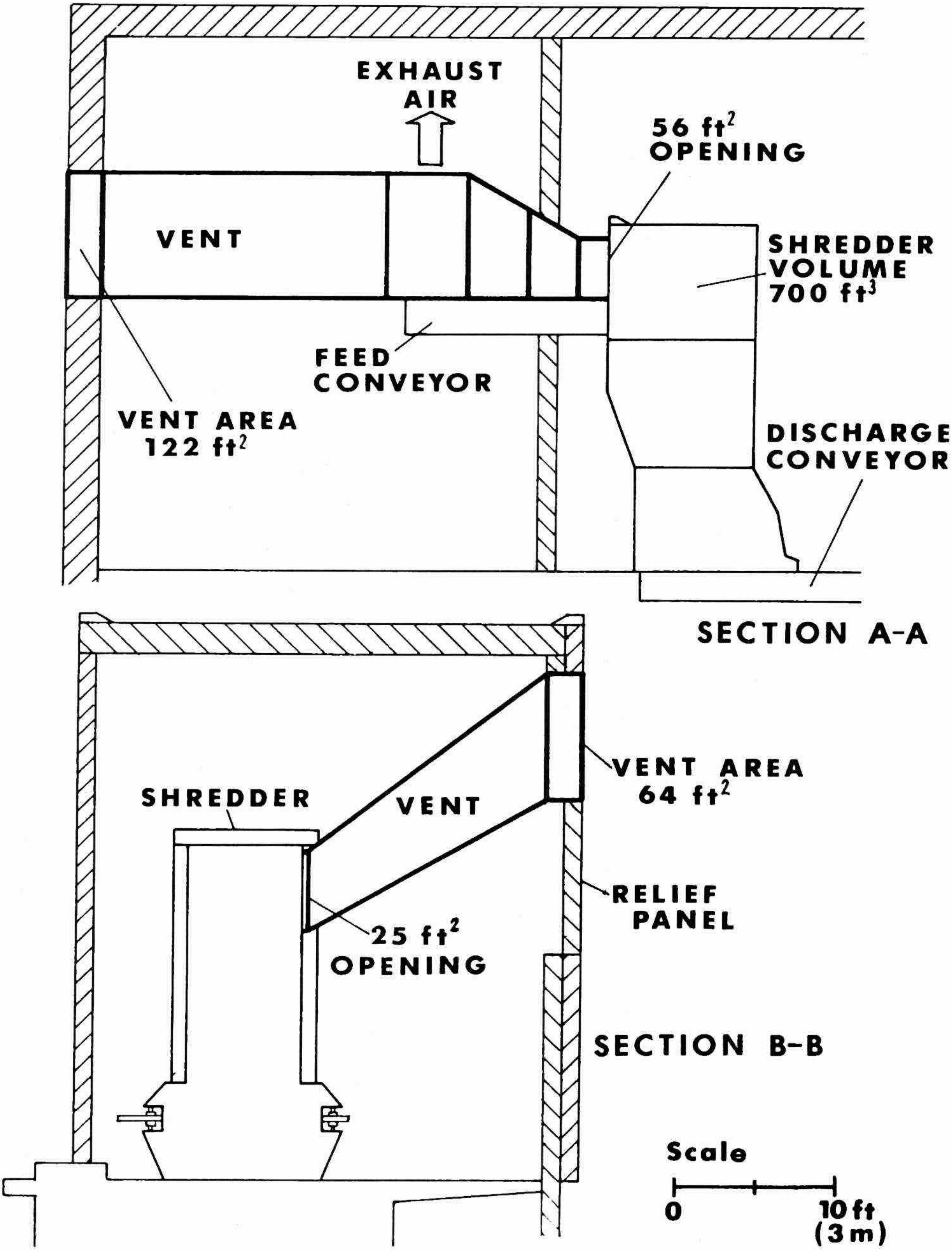

Figure 12 Primary Shredder Venting (Sections)

building. The routing of the general public taking plant tours also had to be altered until the explosion venting modifications were completed.

Performance of Loss Control Measures

The following attempts to highlight some of the key findings established from the fire and explosion experiences at the Experimental Plant for Resource Recovery. Although these observations and conclusions stem from one particular facility with a specific design configuration, it is felt that many of the facets of fire and explosion loss control are generally applicable and of interest to those in the field of solid waste processing.

Most in-plant fires are detected by operating personnel observing flames or smoke or smelling smoke. Plant experience to date has shown that, in general, fires are detected through human observation at least as rapidly as through detection devices. The secondary method of fire detection has been through the internal television monitoring system. Relatively few fires have been detected through in-plant mechanical or electrical devices. Even though the warning rate for such devices may be low compared to human sightings, considerable care should be taken in the selection of appropriate detection devices. At the ERRP, ionization type detectors have been relatively ineffective and questionable performance has been obtained from the heat detectors triggering the carbon dioxide fire extinguishing systems.

In the general area of fire fighting, good success has been obtained using water as an extinguishing agent. Even though extensive sprinkler systems may be designed, considerable attention should be given to ensure good availability of hand- held hoses, thus requiring careful consideration in the location of local hose cabinets. The deluge approach has been highly effective in controlling fires in critical areas of the ERRP.

If emergency dump capability is provided for material on conveyors, keeping burning material in motion may allow easier fire fighting and also may minimize damage to conveyor belting. The concept of keeping burning material in motion excludes pneumatic conveying systems, where such action may only serve to spread the fire.

In plant design considerations, an awareness should be maintained of the dependency of certain fire control systems on other plant services such as electricity or pressurized air. In some cases fire fighting may necessitate the shutting off of all plant electrical services. Electrical rooms should be located to allow ready access for power shutoff during fire fighting activities and also to minimize water damage in the event of fires. Similarly, the location of sprinkler shutoffs should be in accessible areas rather than potentially high risk areas.

There is considerable need to ensure that both plant management and plant operating personnel receive adequate fire fighting training. Similarly, regular safety meetings coupled with operating staff review of fire fighting techniques are essential. One area frequently overlooked is the need to make key fire fighting personnel, if not all fire fighting personnel, aware of plant design and equipment changes.

The local fire station crews of the municipal fire department should be made familiar with the facility, preferably through crew tours where plant layout is explained and in-plant hazards are detailed.

With respect to shredder explosions, general precautions have been well identified. Some of these are:

1. Location of shredders remote from plant personnel;
2. Use of an explosion protection system such as venting or suppression;
3. Manual inspection to remove hazardous materials prior to shredding;
4. Use of blast resistant barricades;
5. Control of waste receipts.

In addition to these general precautions, consideration should be given to locating the primary shredder near an outside wall to facilitate provision of explosion vents. Some consideration should also be given to the discharge direction of such vents.

In the ERRP, explosion vents were retrofitted as noted earlier. The value of the vents in minimizing damage has been demonstrated in the three explosions since the vents were installed, particularly for the first explosion after the vents were installed. The fact that the minimum siding damage occurred with the largest explosion is attributed to the effective release of the explosive pressures through the vents. Although the last two explosions were considered minor, this categorization is largely dependent upon the resulting effects of the explosion. Without the vents and the modified exhaust system, either of these incidents may have resulted in damage comparable to one of the earlier explosions.

The continued incidence of explosions in spite of greater efforts to inspect and remove potentially hazardous materials from the waste stream prior to shredding confirms earlier concerns that such inspections would not be totally effective because of the quantity of material being processed. Attempts to control the waste receipts have been ineffective as evidenced by the repeated incidents.

The fact that the shredder was located in a separate building remote from areas frequented by personnel during operations has likely been a major factor in the absence of any personal injuries.

The use of explosion vents for the primary shredder was based upon the premise that they would provide the maximum benefits for the expenditure of any of the alternatives available. As a passive device, a vent is expected to relieve explosion pressures and minimize property damage (unless pressures are sufficient to destroy the vents). The need for maintenance and inspection is minimal and simple, i.e. ensuring that the vent is clear of debris that would reduce the vent area and maintaining the vent covering. Explosion suppression systems are active devices relying on a combination of electronic and mechanical components requiring more sophisticated inspection and maintenance procedures to ensure system reliability. Their value in minimizing damage from explosions which can be suppressed is undeniable; however, the cost of installation and maintenance must be weighed against the potential damage or the downtime which could result without such a system. Design of the shredder area should be such that the potential damage from an explosion is minimized. Consensus of the waste processing industry now is that explosion vents be mandatory and that explosion suppression systems be used to provide supplementary protection.

CONCLUSIONS

Based on the experiences at the Ontario Ministry of the Environment's Experimental Plant for Resource Recovery and other similar facilities throughout North America, fire and explosion incidents arising from solid waste processing appear inevitable. Once recognition is given to the existence of these hazards, attention should be focused on the areas of risk identification, fire and explosion prevention, and loss control measures.

It is essential that both management and operating staff receive adequate training in hazard recognition as well as fire fighting techniques and that provision be made for continual updating of staff capabilities in these areas. Such training becomes critical when experience has indicated that loss control measures are at least as dependent on the performance of operating staff as compared to the performance of detection devices and protection systems.

RECOMMENDATIONS

1. Fire loss control measures should be provided both for general protection of buildings and equipment (e.g. sprinklers) and for rapid response for extinquishing fires in high risk areas (e.g. deluge systems on shredders and associated conveyors).
2. Explosion loss control measures should be designed to minimize damage in the event of an explosion. Inspection of waste should be considered only as a means of minimizing the frequency or severity of explosions rather than eliminating them. The original design of the facilities (location of shredders, venting) should be such as to minimize physical damage and hazards to personnel; isolation of the primary shredder is a key means of achieving this goal.
3. Backup fire protection services should be available and staff trained in their use in the event that more sophisticated fire protection systems are disabled through loss of normal building services (compressed air, electricity).
4. All staff should be properly trained to recognize and respond to emergency situations.
5. The local fire department should be made familiar with the plant layout and potential hazard areas through plant inspections.

REFERENCES

1.) Ahlberg, N.R. and Boyko, B.I. "Research and Development Facilities at the Ontario Centre for Resource Recovery", Proceedings of 1978 National Waste Processing Conference, May, 1978, pp. 341-349.

2.) Zalosh, R.G., "Explosion Protection in Refuse Shredding", Proceedings of the Fifth National Congress on Waste Management Technology and Resource Recovery and Energy, Dec. 1976.

3.) "Guide for Explosion Venting NFPA 68-1978", National Fire Protection Association, Boston, Ma.

TD
794.5
.A35
C66
1980